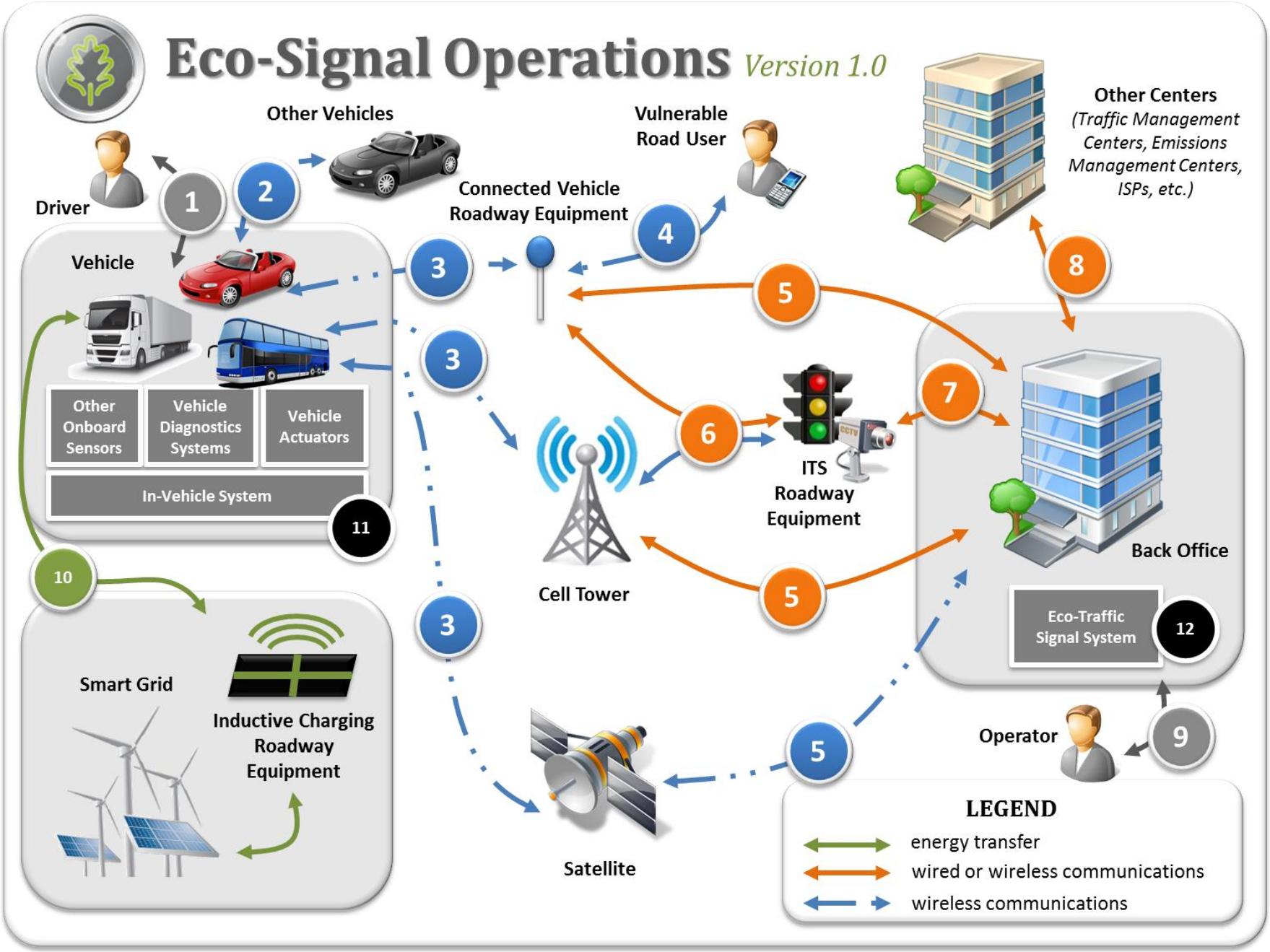
Eco-Signal Operations Version 1.0
Other Vehicles
Vulnerable Road User
Other Centers (Traffic Management Centers, Emissions Management Centers, ISPs, etc.)
Driver
Connected Vehicle Roadway Equipment
Vehicle
Other Onboard Sensors
Vehicle Diagnostics Systems
Vehicle Actuators
In-Vehicle System
ITS Roadway Equipment
Cell Tower
Back Office
Eco-Traffic Signal System
Smart Grid
Inductive Charging Roadway Equipment
Satellite
Operator
LEGEND
energy transfer
wired or wireless communications
wireless communications

Eco-Signal Operations Transformative Concept

The Eco-Signal Operations Transformative Concept includes the use of connected vehicle technologies to decrease fuel consumption and decrease GHGs and criteria air pollutant emissions on arterials by reducing idling, reducing the number of stops, reducing unnecessary accelerations and decelerations, and improving traffic flow at signalized intersections. As the AERIS Program defined the Eco-Signal Operations Transformative Concept, it initially envisioned four applications: (1) Eco-Traffic Signal Timing, (2) Eco-Traffic Signal Priority, (3) Eco-Approach and Departure at Signalized Intersections, and (4) Connected Eco-Driving. These applications are summarized below.

- **Eco-Traffic Signal Timing** | This application is similar to current adaptive traffic signal systems; however the application's objective is to optimize traffic signals for the environment. The application collects data from vehicles, such as vehicle location, speed, GHG and other emissions data using connected vehicle technologies. It then processes these data to develop operational strategies at signalized intersections focused on reducing fuel consumption and overall emissions at the intersection, along a corridor, or for a region. The application evaluates traffic and environmental parameters at each intersection in real-time and adapts so the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact.

- **Eco-Traffic Signal Priority** | This application allows either transit or freight vehicles approaching a signalized intersection to request signal priority. These applications consider the vehicle's location, speed, vehicle type (e.g., Alternative Fuel Vehicles) and associated GHG and other emissions to determine whether priority should be granted. Information collected from vehicles approaching the intersection, such as a transit vehicle's adherence to its schedule, or the number of passengers on the transit vehicle may also be considered in granting priority. If priority is granted, the traffic signal would hold the green on the approach until the transit vehicle clears the intersection. This application does not consider signal pre-emption, which is reserved for emergency response vehicles.

- **Eco-Approach and Departure at Signalized Intersections** | This application uses wireless data communications sent from roadside equipment (RSE) unit to connected vehicles to encourage "green" approaches to signalized intersections. This includes broadcasting SPaT and Geographic Information Description (GID). Vehicle status messages, sent from nearby vehicles using V2V communications, are also considered by the application. Upon receiving this information, on-board equipment (OBE) units perform calculations to provide speed advice to the driver of the vehicle allowing the driver to adapt the vehicle's speed to pass the next traffic signal on green or to decelerate to a stop in the most eco-friendly manner. This application also considers a vehicle's acceleration as it departs from a signalized intersection and start-stop technology as a vehicle is stopped at a traffic signal.

- **Connected Eco-Driving** | This application provides customized real-time driving advice to drivers so that they can adjust their driving behavior to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration, and optimal deceleration profiles based on prevailing traffic conditions and interactions with nearby vehicles. The application also provides feedback to drivers on their driving behavior to encourage drivers to drive in a more environmentally efficient manner. Finally, the application may also include vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy (e.g., changes gears, switches power sources, or reduces its speed in an eco-friendly manner as the vehicle approaches a traffic signal).

Breakout Session Questions

1. Does the Data Flow Diagram accurately depict the Transformative Concept?
2. Do you agree with the data being exchanged between the actors?
3. Is there any data identified in the read-ahead package that is unlikely to be exchanged between actors?
4. Is there any data that should be exchanged between actors that is not identified in the read-ahead package?
5. Based on what you heard about the Eco-Signal Operations Transformative Concept, what aspect stands out? What is useful to you as a deployer or operator? Are there components of this Transformative Concept that you would consider implementing in the next 5 years? 10 years? 20 years?
6. How would an algorithm that optimizes a traffic signal for the environment differ from an algorithm that optimizes a traffic signal for mobility? Would you expect to see significant mobility trade-offs by optimizing traffic signals for the environment?
7. In your opinion, when would an agency operating a traffic signal system decide to optimize a traffic signal system for the environment instead of mobility? Is this likely to occur?
8. Based on what you have heard about this Transformative Concept, are there components of this Transformative Concept that could be developed for a proof-of-concept (PoC) prototype application? If so, what would a PoC prototype application look like? How could the PoC prototype application be implemented in a real-world environment considering that all vehicles will be equipped with connected vehicle technologies?

Table 1. Eco-Signal Operations Data Flows and Actions

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
	**In-Vehicle System and Driver**	<u>In-Vehicle System sends to Driver</u> • Eco-driving recommendations (e.g., recommended driving speeds, driver feedback, etc.) • SPaT information (e.g., time to red, etc.) • Traffic conditions • Environmental conditions (e.g., code red air quality alerts) • Road weather conditions • Status of an electric vehicle's electric charge and charge received from inductive charging field infrastructure <u>Driver Sends to In-Vehicle System</u> • Activation of Application (e.g., activate eco-driving application) • Updates to configurable parameters	• IVS-DC-01: Collect Driver Input • IVS-D-01: Provide Eco-Driving Information to the Driver • IVS-DI-01: Provide Driver Interface
	**In-Vehicle System and Other Vehicles**	<u>In-Vehicle System sends to Other Vehicles</u> • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) <u>Other Vehicles send to In-Vehicle System</u> • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.)	• IVS-DC-07: Receive Vehicle Status Data from Other Vehicles • IVS-D-03: Disseminate Vehicle Status Information
	**In-Vehicle System and Connected Vehicle Roadway Equipment** **In-Vehicle System and Cell**	<u>In-Vehicle System sends to Connected Vehicle Roadway Equipment, Cell Tower, and Satellite</u> • Traffic signal priority requests • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel	• IVS-DC-02: Receive Traffic Conditions • IVS-DC-03: Receive Environmental Conditions • IVS-DC-04: Collect Signal Phase and Timing (SPaT) Data • IVS-DC-05: Collect Geographic Information Description Data

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
	Tower **In-Vehicle System and Satellite**	consumption) <u>Connected Vehicle Roadway Equipment, Cell Tower, and Satellite sends to the In-Vehicle System</u> • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts) • Road weather conditions (e.g., pavement conditions) • Signal Phase and Timing (SPaT) data • Geographic Information Description Data (e.g., lane geometries, lane configurations, posted speed limits, etc.)	• IVS-D-02: Send Traffic Signal Priority Request • IVS-D-03: Disseminate Vehicle Status Data • IVS-D-04: Disseminate Vehicle Status Environmental Data
4	**Connected Vehicle Roadway Equipment and Vulnerable Road User**	<u>Vulnerable Road User sends to Connected Vehicle Roadway Equipment</u> • Traffic data (e.g., pedestrian presence at signalized intersections)	• ETSS-DC-02: Collect Traffic Data
5	**Connected Vehicle Roadway Equipment and Eco-Traffic Signal System** **Cell Tower and Eco-Traffic Signal System** **Satellite and Eco-Traffic Signal System**	<u>Connected Vehicle Roadway Equipment, Cell Tower, and Satellite sends to Eco-Traffic Signal System</u> • Traffic signal priority requests • Vehicle status data (e.g., vehicle's location, heading, speed, acceleration, braking status, size, etc.) • Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) • Pedestrian presence at signalized intersections	• ETSS-DC-01: Collect Traffic Signal Priority Requests • ETSS-DC-02: Collect Traffic Data • ETSS-DC-03: Collect Environmental Data • ETSS-D-03: Disseminate Traffic Conditions to Vehicles • ETSS-D-05: Disseminate Environmental Conditions to Vehicles • ETSS-D-07: Disseminate Geographic Information Descriptions

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		Eco-Traffic Signal System sends to Connected Vehicle Roadway Equipment, Cell Tower, and Satellite • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Environmental conditions (e.g., air quality information, code red air quality alerts) • Road weather conditions (e.g., pavement conditions) • Geographic Information Description Data (e.g., lane geometries, lane configurations, posted speed limits, etc.)	
6	**Connected Vehicle Roadway Equipment and ITS Roadway Equipment** **Cell Tower and ITS Roadway Equipment**	ITS Roadway Equipment sends to Connected Vehicle Roadway Equipment • Signal Phase and Timing (SPaT) data • Geographic Information Description (e.g., lane geometries, lane configurations, posted speed limits, etc.) Connected Vehicle Roadway Equipment to ITS Roadway Equipment • Traffic signal priority request • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration) • Pedestrian presence at signalized intersections	• IVS-DC-04: Collect Signal Phase and Timing (SPaT) Data • ETSS-DC-01: Collect Traffic Signal Priority Requests • ETSS-D-07: Disseminate Geographic Information Descriptions
7	**ITS Roadway Equipment and Eco-Traffic Signal System**	ITS Roadway Equipment sends to Eco-Traffic Signal System • Traffic data (e.g., speed, volume, occupancy, pedestrian calls, etc.) • Environmental data (e.g., air quality data, etc.) • Road weather data (e.g., road friction, precipitation, temperature, etc.) • Traffic signal operational status (e.g., current timing in operation) Eco-Traffic Signal System sends to ITS Roadway Equipment • Traffic signal priority data (e.g., time to extend the green or advance the green for priority)	• ETSS-DC-02: Collect Traffic Data • ETSS-DC-03: Collect Environmental Data • ETSS-DC-04: Collect Traffic Signal Operational Status Data • ETSS-D-01: Disseminate Traffic Signal Priority Data • ETSS-D-06: Disseminate Traffic Signal

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		• Traffic signal timing plans • Geographic Information Description Data (e.g., lane geometries, lane configurations, posted speed limits, etc.)	Timing Plans
8	**Eco-Traffic Signal System and Other Centers**	<u>Eco-Traffic Signal System sends to Other Centers</u> • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Traffic signal timing plans in operation • Environmental conditions (e.g., air quality data, code red air quality alerts) • Road weather data (e.g., road conditions) • Geographic Information Description Data (lane geometries, lane configurations, posted speed limits, etc.) <u>Other Centers sends to Eco-Traffic Signal System</u> • Traffic conditions (e.g., link speeds, queues, incidents, travel times, etc.) • Traffic signal timing plans in operation • Environmental conditions (e.g., air quality data, code red air quality alerts) • Road weather data (e.g., road conditions) • Geographic Information Description Data (e.g., lane geometries, lane configurations, posted speed limits, etc.)	• ETSS-DC-02: Collect Traffic Data • ETSS-DC-03: Collect Environmental Data • ETSS-DC-05: Collect Geographic Information Description Data • ETSS-D-02: Disseminate Traffic Information to Other Centers • ETSS-D-04: Disseminate Environmental Conditions to Other Centers
9	**Eco-Traffic Signal System and Operator**	<u>Eco-Traffic Signal System sends to Operator</u> • Traffic conditions • Environmental conditions • Road weather conditions • Performance measures • Traffic signal system operational status	• ETSS-DC-05: Collect Geographic Information Description Data • ETSS-DC-06: Collect Operator Input • ETSS-UI-01: User Interface

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		• Archived data Operator sends to Eco-Traffic Signal System • Operator inputs (e.g., creating new traffic signal timing plans, implementing timing plans, or adding new equipment (e.g., new traffic signals) to the system) • Geographic Information Description Data (lane geometries, lane configurations, posted speed limits, etc.)	
10	**Inductive Charging Roadway Equipment and Vehicle**	Inductive Charging Roadway Equipment sends to Vehicle • Request for charge • Inductive charge • Request for payment Vehicle sends to Inductive Charging Roadway Equipment • Approval to receive inductive charge • Payment information • Provide energy back into the Smart Grid	• IVS-DC-09: Receive Inductive Charge

11	**In-Vehicle System**	• Collect Data
		  ○ Driver input (e.g., activation of application, system parameters, etc.)
		  ○ Traffic conditions (e.g., current and predicted traffic speeds, travel times, incidents, queues, etc.)
		  ○ Environmental conditions (air quality information, code red day alert, etc.)
		  ○ Road weather conditions (e.g., pavement conditions)
		  ○ Signal phase and timing (SPaT) data
		  ○ Geographic Information Description data (e.g., lane geometries, lane configurations, posted speed limits, etc.)
		  ○ Data for signal priority requests (e.g., passenger data and adherence to transit schedules) – transit vehicles only
			• IVS-DC-01: Collect Driver Input
			• IVS-DC-02: Receive Traffic Conditions Data
			• IVS-DC-03: Receive Environmental Conditions
			• IVS-DC-04: Collect Signal Phase and Timing (SPaT) Data
			• IVS-DC-05: Collect Geographic Information Description Data
			• IVS-DC-06: Collect Data for Signal

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		○ Data for transit signal priority requests (e.g., truck load, truck weight, etc.) ○ Vehicle diagnostics data (e.g., engine, emissions, GPS, and onboard sensor data) ○ Vehicle status data from nearby vehicles (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) ○ Inductive charge • <u>Process Data</u> ○ Determine eco-driving recommendations (e.g., recommended speeds) ○ Determine eco-approach and departure at Signalized Intersections (e.g., recommended speeds, start-stop recommendations) ○ Determine traffic signal priority request strategy ○ Determine vehicle emissions data (e.g., determine BEM for disseminate) • <u>Disseminate Data</u> ○ Eco-driving recommendations to driver and driver feedback ○ Traffic signal priority requests ○ Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) ○ Vehicle status environmental data (e.g., BEM data including the vehicle's fuel type, engine type, current emissions, average emissions, current fuel consumption, and average fuel consumption) • <u>Vehicle Control</u> ○ Vehicle assisted control (e.g., control of vehicle acceleration and speed) ○ Start-stop control (e.g., turn the vehicle's engine on or off) • <u>Driver Interface</u> ○ Activation of Application (e.g., activate eco-driving application)	Priority Requests • IVS-07: Receive Vehicle Status Data from Other Vehicles • IVS-DC-08: Collect Vehicle Diagnostics Data • IVS-DC-09: Receive Inductive Charge • IVS-DP-01: Determine Eco-Driving Recommendations • IVS-DP-02: Determine Eco-Approach and Departure at Signalized Intersections • IVS-DP-03: Determine Traffic Signal Priority Request Strategy • IVS-DP-04: Determine Vehicle Emissions Data • IVS-D-01: Provide Eco-Driving Information to Driver • IVS-D-02: Send Traffic Signal Priority Request • IVS-D-03: Disseminate Vehicle Status Data • IVS-D-04: Disseminate Vehicle Status Environmental Data • IVS-VC-01: Provide Eco-Driving Vehicle Assisted Control Strategy • IVS-VC-02: Provide Start-Stop Capabilities • IVS-DI-01: Provide Driver Interface

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		○ Updates to configurable parameters ○ Eco-driving recommendations (e.g., recommended driving speeds, driver feedback, etc.) ○ SPaT information (e.g., time to red, etc.) ○ Traffic conditions ○ Environmental conditions (e.g., code red air quality alerts) ○ Road weather conditions ○ Status of an electric vehicle's electric charge and charge received from inductive charging field infrastructure	
12	**Eco-Traffic Signal System**	• <u>Collect Data</u> ○ Traffic signal priority requests and justifications (e.g., schedule, number of passengers, schedule adherence) ○ Traffic data (e.g., speeds, volumes, occupancy, vehicle types, turning movements, CCTV images, incidents, pedestrian calls at traffic signals, etc.) ○ Environmental data (e.g., vehicle emissions, local air conditions, etc.) ○ Road weather conditions road friction, precipitation, temperature, etc.) ○ Operational status of traffic signal system and other devices ○ Geographic Information Description data (e.g., lane geometries, lane configurations, posted speed limits, etc.) ○ Operator input (i.e., new roadway configuration, new signal installation, new timing plans, activation timing plan, etc.) • <u>Process Data</u> ○ Process traffic data ○ Generate predicted traffic conditions ○ Process environmental data ○ Generate predicted emissions profile ○ Provide traffic signal priority decision support capabilities ○ Generate traffic signal timing strategy (e.g., determine eco-timing strategy)	• ETSS-DC-01: Collect Traffic Signal Priority Requests • ETSS-DC-02: Collect Traffic Data • ETSS-DC-03: Collect Environmental Data • ETSS-DC-04: Collect Traffic Signal Operational Status Data • ETSS-DC-05: Collect Geographic Information Description Data • ETSS-DC-06: Collect Operator Input • ETSS-DP-01: Process Traffic Data • ETSS-DP-02: Generate Predicted Traffic Conditions • ETSS-DP-03: Process Environmental Data • ETSS-DP-04: Generate Predicted Emissions Profile • ETSS-DP-05: Provide Traffic Signal Priority Decision Support Capabilities

ID	ACTORS	DATA FLOW / ACTION	RELATED USER NEEDS
		• Disseminate Data ○ Traffic signal priority data (e.g., time to extend the green or advance the green for priority) ○ Traffic signal timing plans ○ Traffic conditions (e.g., current and predicted traffic speeds, travel times, volumes, incidents, queues, etc.) ○ Environmental conditions (e.g., air quality, vehicle emissions at intersection level, corridor level, etc.) ○ Road weather conditions (e.g., pavement conditions) ○ Geographic Information Description data (e.g., lane geometries, lane configurations, posted speed limits, etc.) • User Interface ○ Traffic conditions ○ Environmental conditions ○ Road weather conditions ○ Performance measures ○ Traffic signal system operational status ○ Archived data ○ Operator inputs (e.g., creating new traffic signal timing plans, implementing timing plans, or adding new equipment (e.g., new traffic signals) to the system)	• ETSS-DP-06: Generate Traffic Signal Timing Strategy • ETSS-D-01: Disseminate Traffic Signal Priority Data • ETSS-D-02: Disseminate Traffic Information to Other Centers • ETSS-D-03: Disseminate Traffic Conditions to Vehicles • ETSS-D-04: Disseminate Environmental Conditions to Other Centers • ETSS-D-05: Disseminate Environmental Conditions to Vehicles • ETSS-D-06: Disseminate Traffic Signal Timing Plans • ETSS-D-07: Disseminate Geographic Information Descriptions • ETSS-DA-01: Archive Data • ETSS-DA-02: Determine Performance Measures • ETSS-UI-01: User Interface

Actor and System Definitions

- **Connected Vehicle Roadway Equipment (includes RSE, cell tower, and Satellite)** | The Connected Vehicle Roadway Equipment actor includes the RSE units distributed on and along the roadway. These devices are capable of both transmitting and receiving data using DSRC radios, using the 5.9 GHz band approved for DSRC use by the FCC. The devices may also support other wireless communications, such as cellular and Wi-Fi communications. RSE units support the appropriate IEEE and SAE standards (IEEE 802.11p, IEEE 1609 family, and SAE J2735). The Connected Vehicle Roadway Equipment Actor also includes local processing capabilities to support processing of data at the roadside.

- **Driver** | The Driver actor represents the human entity that operates a licensed vehicle on the roadway. Included are operators of private, transit, and commercial vehicles where the data being sent or received is not particular to the type of vehicle. Thus, this actor originates driver requests and receives driver information that reflects the interactions which might be useful to all drivers, regardless of vehicle classification.

- **Eco-Traffic Signal System** | The Eco-Traffic Signal System is a computerized transportation system that employs communication technology to gather traffic and environmental information from multiple sources including ITS Roadway Equipment, Connected Vehicle Roadway Equipment, and other systems. The system then processes these data to develop operational strategies at signalized intersections, focused on reducing fuel consumption and overall emissions at the intersection, along a corridor, or for a region. The Eco-Traffic Signal System evaluates traffic and environmental parameters at each intersection every cycle in real-time and adapts to fluctuating traffic and environmental conditions through its optimization algorithm. Signal timing recalculates every few seconds to respond to real-time and predicted traffic conditions. Together, these features allow the system to readily adapt to actual traffic volumes and environmental conditions so that the traffic network operation is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact. The Eco-Traffic Signal System also supports the implementation of eco-traffic signal priority. The system considers criteria such as the location, speed, heading, and emissions profile of the requesting vehicle as well as other vehicles approaching the intersection, and a transit vehicle's adherence to schedule when granting priority at the signalized intersection. If it is determined that priority should be granted, the Eco-Traffic Signal System alerts the traffic signal controller that a priority needs to be granted and provides information about the amount of time to extend the green signal to adjust the signal for the priority.

- **Emissions Management Center (Other Centers)** | The Emissions Management Center actor provides the capabilities for air quality managers to monitor and manage air quality. These capabilities include collecting emissions data from distributed emissions sensors within the Roadway actor and from Vehicle actors, and ingesting regional air quality data from external sources and sensors such as operated by the National Weather Service (NWS) or the EPA. These sensors monitor general air quality for an area and also monitor the emissions of individual vehicles on the roadway. The sector emissions measures are collected, processed, and used to identify sectors exceeding or predicted to exceed pre-defined pollution levels. This information is provided to Traffic Management actors to implement strategies intended to reduce emissions in and around the problem areas. This actor provides any functions necessary to inform the violators and otherwise ensure timely compliance with emissions standards. This actor may co-reside with the Traffic Management actor or may operate in its own distinct location depending on regional preferences and priorities.

- **Inductive Charging Roadway Equipment** | The inductive Charging Roadway Equipment actor includes roadside infrastructure deployed along the roadway that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables inductive charging of electric vehicles including cars, trucks, and buses. Roadside Charging Infrastructure supports static charging capable of transferring electric power to a vehicle parked in a garage or on the street and vehicles stopped at a traffic light. It also supports charging vehicles moving at highway speeds.

- **ITS Roadway Equipment** | The ITS Roadway Equipment actor includes the equipment distributed on and along the roadway that monitors and controls traffic and monitors and manages the roadway itself. Equipment includes traffic detectors, environmental sensors, traffic signals, highway advisory radios (HAR), DMSs, CCTV cameras, and video image processing systems, grade crossing warning systems, and freeway ramp metering systems. HOV lane management, reversible lane management functions, and barrier systems that control access to transportation infrastructure such as roadways, bridges, and tunnels are also supported. This actor also provides the capability for environmental monitoring including sensors that measure road conditions, surface weather, and vehicle emissions. In adverse conditions, automated systems can be used to apply anti-icing materials, disperse fog, etc.

- **In-Vehicle System** | The In-Vehicle System allows drivers of vehicles to opt-in to applications that provide real-time driving so that they can adjust driving behavior to save fuel and reduce emissions. The advice includes recommended driving speeds, optimal acceleration, and optimal deceleration profiles on arterials. The system may also consider vehicle-assisted strategies where the vehicle automatically implements the eco-driving strategy. In-Vehicle System includes recommendations for eco-driving at signalized intersections, stop signs, yield signs, and on arterials between intersections. Additional details on eco-driving strategies for freeways are described in the Eco-lanes Operational Description document. The In-Vehicle System uses traffic data, environmental data, vehicle status data from other vehicles, terrain information, and SPaT information available through DSRC or other wireless communication, between traffic signals and vehicles.

These data are then processed to determine optimal eco-driving strategies which in turn are disseminated to the driver through an operator interface. For example, the system may alert the driver that he or she cannot traverse the signalized intersection before the signal turns red. After receiving the alert, the driver may slowly decelerate to the stop bar instead of continuing on the current speed and having to apply a hard brake at the end. The system will consider potential interactions with other vehicles, traffic conditions downstream, and traffic signal timing at other traffic signals downstream. Additionally, the system considers the vehicle's acceleration from the signalized intersection if the vehicle slows down or comes to a stop at the signalized intersection. The In-Vehicle System also includes start-stop capabilities that automatically shut down and restart the vehicle's engine reducing the amount of time the engine spends idling, thereby reducing fuel consumption and emissions. This is advantageous for vehicles as they spend significant amounts of time waiting at traffic lights or frequently are stopped due to traffic congestion.

- **Operator** | The Operator actor represents the human entity that directly interfaces with the Eco-Traffic Signal System.

- **Other On-Board Sensors** | The Other On-board Sensors Actor represents sensors that may be installed on vehicles to collect traffic or environmental conditions data. For example, sensors may be equipped on a vehicle to measure atmospheric, surface (i.e., pavement and soil), and/or hydrologic conditions.

- **Vehicle** | The Vehicle actor provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and environmentally efficient travel. Both one-way and two-way communications options, including 5.9 GHz band approved for DSRC use by the FCC and other wireless communications such as cellular, support a spectrum of information services. This capability allows the vehicle actor to disseminate information about its status (i.e., current speed, acceleration, braking, and average emissions) to other vehicles or to the Connected Vehicle Roadway actor. Advanced sensors, processors, enhanced driver interfaces, and actuators in the Vehicle actor complement the driver information services so that, in addition to making informed mode and route selections, the driver travels these routes in a safer and more consistent manner. This Actor may also include more advanced functions that assume limited control of the vehicle to maintain safe headway.

- **Traffic Management Center (Other Centers)** | The Traffic Management Center actor monitors and controls traffic and the road network. It represents the functionality provided by centers that manage a broad range of transportation facilities including freeway systems, rural and suburban highway systems, and urban and suburban traffic control systems. This actor communicates with the Roadway actor to monitor and manage traffic flow and monitor the condition of the roadway, surrounding environmental conditions, and field equipment status (e.g., traffic signals). This actor also manages traffic and transportation resources to support allied agencies in responding to, and recovering from, incidents ranging from minor traffic incidents through major disasters. The Traffic Management actor supports HOV lane management and coordination, road pricing, and other demand management policies that can alleviate congestion and influence mode selection. The actor communicates with other Traffic Management actors to coordinate traffic information and control strategies in neighboring jurisdictions.

- **Vehicle Diagnostic System** | The Vehicle Diagnostic Systems actor represents computer-based systems, located on vehicles, designed to monitor the performance of some of an engine's major components including those responsible for controlling emissions.

- **Vehicle Actuators** | The Vehicle Actuator actor represents an electromechanical device such as a relay, solenoid, or motor. Within the vehicle, computers use sensor data to control different systems on the vehicle through the use of actuators. Actuators can adjust engine idle speed, change suspension height, regulate the fuel metered into the system, accelerate or decelerate the vehicle, or implement the braking system.

- **Vulnerable Road User** | Non-motorized road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation Vulnerable road users